ANTHROPOLOGY AND GEOGRAPHY
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BITING DOWN ON SOFT TISSUE:
Masticatory Musculature In Two Early Eocene Faunivorous Mammals (Primates, Creodonta)

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INTRODUCTION

In this study, comparative functional anatomy is examined on the mandible, zygomatic arch, & sagittal crest of early Eocene mammalian faunivores for insights on dietary adaptations.

HYPOTHESES

The more pronounced the bone features are, the larger & more powerful are the mastication muscles. I hypothesize that whereas the nonprimate faunivore, *Oxyaena*, will have larger muscles for mastication suggesting a more forceful bite, the faunivorous primate, *Tetonius*, will have a different skeleto-muscle arrangement. Such variation would be due to distinct eating behaviors. I further propose that *Oxyaena* will be most similar to the modern wolf (*Canis lupus*).

FOSSIL SPECIMENS

The following fossil specimens were analyzed from the Primate Origins Lab collection at CSU:

- *Oxyaena* (DMNH 126358)
- *Tetonius* (DMNH 65043)

EXTANT SPECIMENS

The following extant mammalian head specimens were examined through dissection. These specimens are housed in the Anatomy/Zoology Lab, CSU, & dissection was performed under the advisement of Dr. Jeremy Delcambre:

- *Canis lupus familiaris* (common dog)
- *Felis catus* (common house cat)
- *Cavia porcellus* (Guinea pig)
- *Oryctolagus cuniculus* (domestic rabbit)
- *Equus caballus* (horse)
- *Bos Taurus* (cow)

METHODS

I compared the morphology of an extinct faunivorous tarsier-like primate (*Tetonius*, Omomyoidea) & an extinct faunivore (*Oxyaena*, Creodonta). The mandible, zygomatic arch, & sagittal crest were examined to determine masticatory musculature. The fossil mandibular jaw elements were combined with published cranio-facial images from other individuals of the same taxa with the addition of my illustrations of masticatory muscles (*m. temporalis*, *m. masseter*, & *m. digastricus*) based on dissection research on extant mammalian masticatory anatomy.

RESULTS

The results yield insights pertinent to hypotheses regarding distinctions in primate & non-primate jaw bite force & differences in anterior food procurement adaptations.

<u>*Oxyaena*</u> skull morphology has large surface areas for the origins & insertions of both *m. temporalis* & *m. masseter*. This suggests strong jaw action for clamping with a locking jaw on its prey.

<u>*Tetonius*</u> (with the addition of skull morphology from its closest modern analog, *Tarsius syrichta*) has a less defined skull morphology for the the origins & insertions of both *m. temporalis*, *m. masseter*, & *m. digastricus*. The largest muscle (based on muscle surface area & thickness) is *m. masseter*, with *m. temporalis* being flat & underdeveloped. This suggests, in comparison to *Oxyaena*, that clamping down on prey was not necessary.

DISCUSSION

<u>*Oxyaena*</u> shows immense development in all three masticatory muscles. The thickness of *m. temporalis* is roughly 2.5 cm based on the sagittal crest where the largest part of *m. temporalis* is located. *M. masseter* has a maximum thickness twice that of *m. temporalis* (roughly 5 cm). The length of *m. digastricus* (roughly 13 cm) indicates wide depression (opening) of the mandible. The skull length of *Oxyaena* (about 24.5 cm), with the mastication muscles covering roughly 14 cm of the skull, indicates that the mastication muscles cover 57.14% of the skull. Note that olfactory senses are more developed in nonprimate mammals & are responsible for muzzle elongation. For comparative purposes, I analyzed the following faunivores: *Crocuta crocuta* (spotted hyena, observed in the Zooarchaeology Lab, CSU), *Canis lupus* (grey wolf), & *Panthera leo* (African lion, male, observed in the Zooarchaeology Lab, CSU). *C. crocuta* morphology allows greater mechanical advantage in *m. temporalis* (Buckland-Wright, 2009). Based on cranial measurements, the estimated *m. temporalis* thickness is about 3 cm & *m. masseter* is roughly 5 cm in thickness. In contrast to *Oxyaena*, the mastication muscles cover 63.46% of the skull. In *C. lupus* the *m. temporalis* thickness is about 1.4 cm & *m. masseter* thickness is roughly 5.1 cm & the mastication muscles cover 47.35% of the skull. Lastly, *P. leo* has *m. temporalis* thickness of roughly 1 cm but *m. masseter* is large, at roughly 8.5 cm with mastication muscles covering 44.54% of the skull.

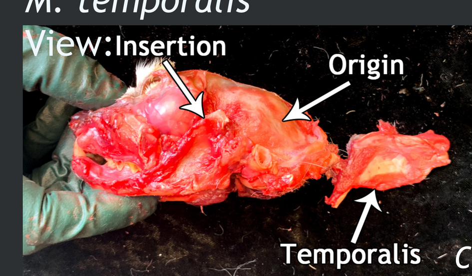
<u>*Tetonius/Tarsius syrichta*</u> has thicknesses for *m. temporalis* of 0.50 cm &, doubling that, *m. masseter* at 1 cm. The length of *m. digastricus* is about 3 cm. The length of the tarsier skull is about 10.7 cm, with mastication muscles covering about 44.86% of the skull. Importantly, *m. masseter* is more developed than *m. temporalis* as suggested by the surface area it covers. This is similar to the pattern of masticatory muscle proportions in guinea pigs & rabbits. *C. porcellus* & *O. cuniculus* have large *m. masseter* with flat *m. temporalis*, which is consistent with increased chewing adaptations. This indicates that *Tetonius/Tarsius syrichta* was adapted for processing foods with cheek teeth, rather than anterior biting & tearing adaptations as seen in *Oxyaena*.

1: DISSECTION ANALYSIS

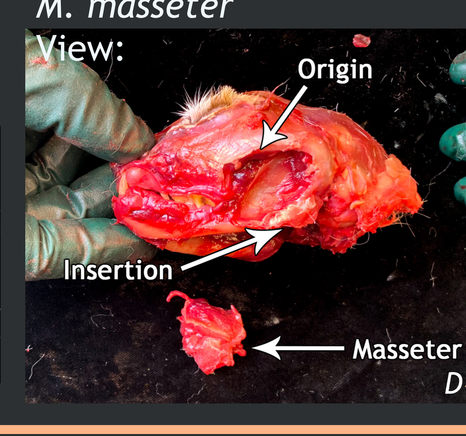
THE CAT HEAD: Under Dissection

Profile of Full Cat Head & Skull (Lateral & Superior View):

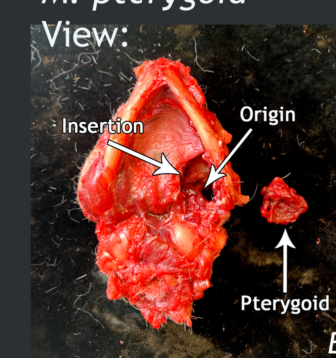
M. temporalis View:

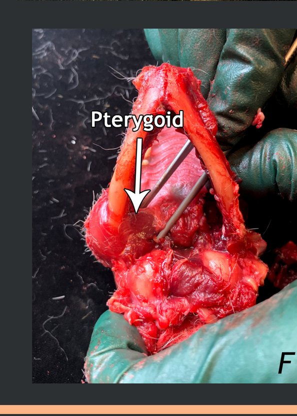


M. masseter View:

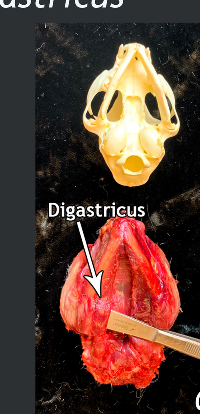


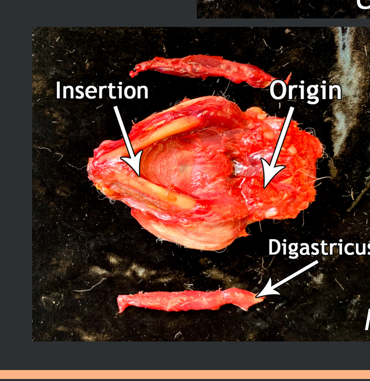
M. pterygoid View:





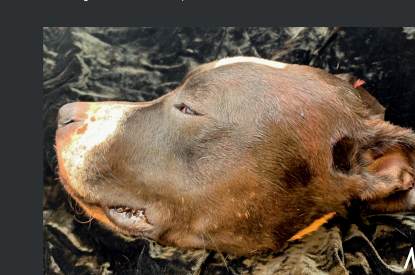
M. digastricus View:



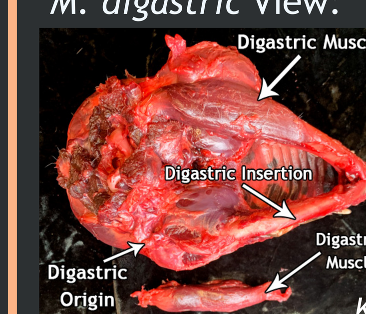


THE DOG HEAD: Under Dissection

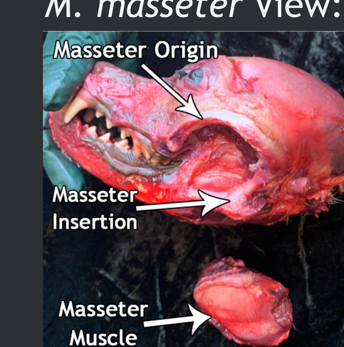
Profile of Dog Head (Lateral) & Skull (Lateral & Superior) View:



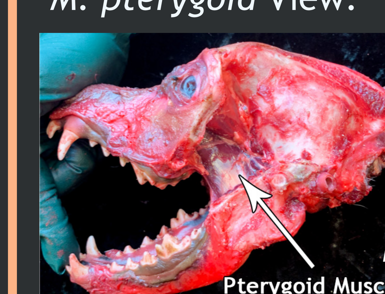
M. digastric View:



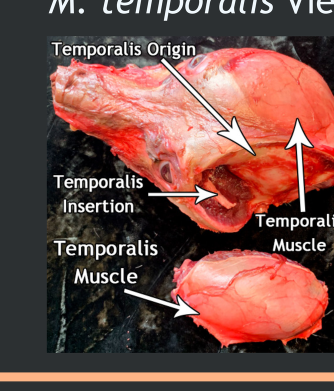
M. masseter View:



M. pterygoid View:



M. temporalis View:



THE DISSECTIONS

In dissection I worked with Dr. Delcambre in the Zoology/Anatomy lab analyzing the muscles of mastication: *m. temporalis*, *m. masseter*, *m. pterygoid*, & *m. digastricus*. We dissected one head of each of the following: dog, cat, guinea pig, rabbit, horse, & cow. These dissections allowed an in-depth view on the different forms of each mastication muscle as well as a better understanding of the origins & insertions for each.

Starting from left, cat head dissection. Image *A*: lateral view of cat head (skin removed) next to cat skull; *B*: superior view of cat head (skin attached) next to cat skull; *C*: *m. temporalis* shown from lateral view, dissected from cat head & placed next to it; *D: m. masseter* shown from lateral view, dissected from cat head & placed next to it; *E: m. pterygoid* shown from inferior view, dissected from cat head & placed next to it; *F: m. pterygoid* shown from inferior view, still attached to cat head; *G: m. digastricus* shown from inferior view, still attached to cat head; *H: m. digastricus* shown from inferior view, dissected from cat head & placed next to it; *I*: dog skull shown in superior view; *J*: dog skull shown in lateral view; *K: m. digastricus* shown from inferior view, dissected from dog head & placed next to it; *L: m pterygoid* shown from lateral view, still attached to dog head; *M*: lateral view of dog head (skin attached); *N: m. masseter* shown from lateral view, dissected from dog head & placed next to it; *O: m. temporalis* shown from superior view, dissected from dog head & placed next to it.

2: ARTISTIC RENDITION & ANALYSES

OXYAENA

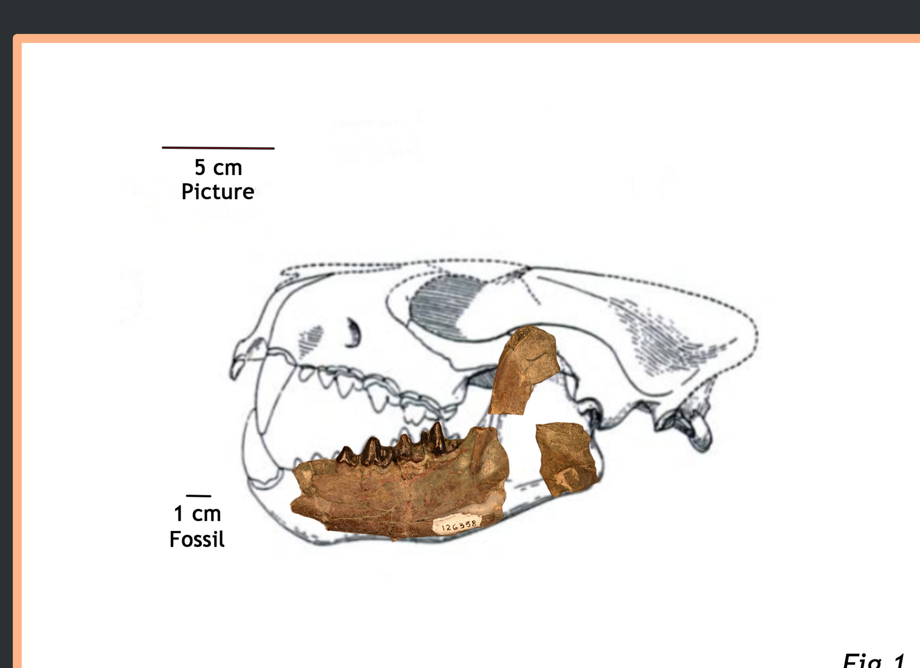


Fig 1: *Oxyaena* skull sketch from *The Beginning of the Age of Mammals* (Rose, 2006) with CSU Primate Origins Lab specimen (DMNH 126358) superimposed on top of it.

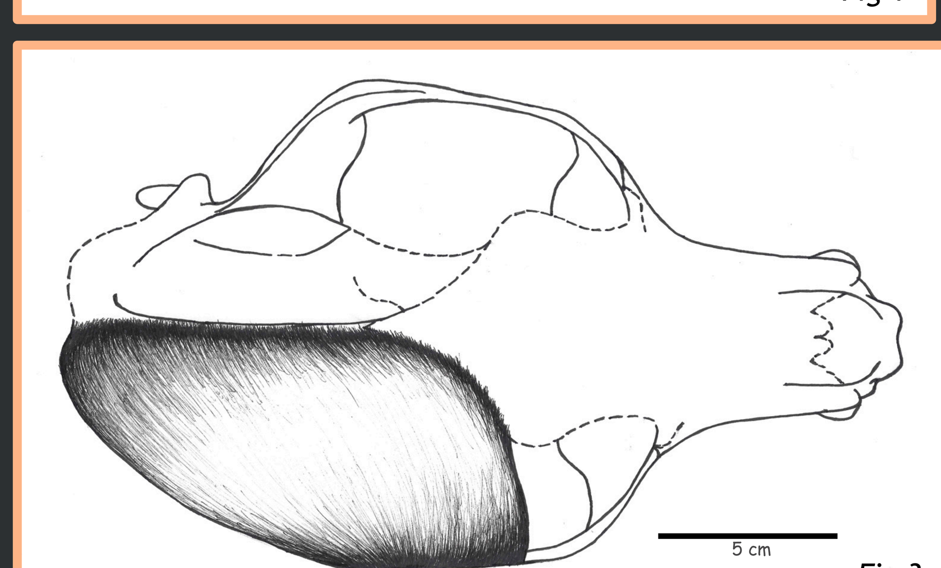


Fig 3: Superior view of *Oxyaena* skull copied from Rose (2006). *M. temporalis* is illustrated on top of the Rose (2006) skull. The origin is along the sagittal crest & the insertion is along the mandibular ramus & part of the zygomatic arch (imbedding itself within *m. masseter*).

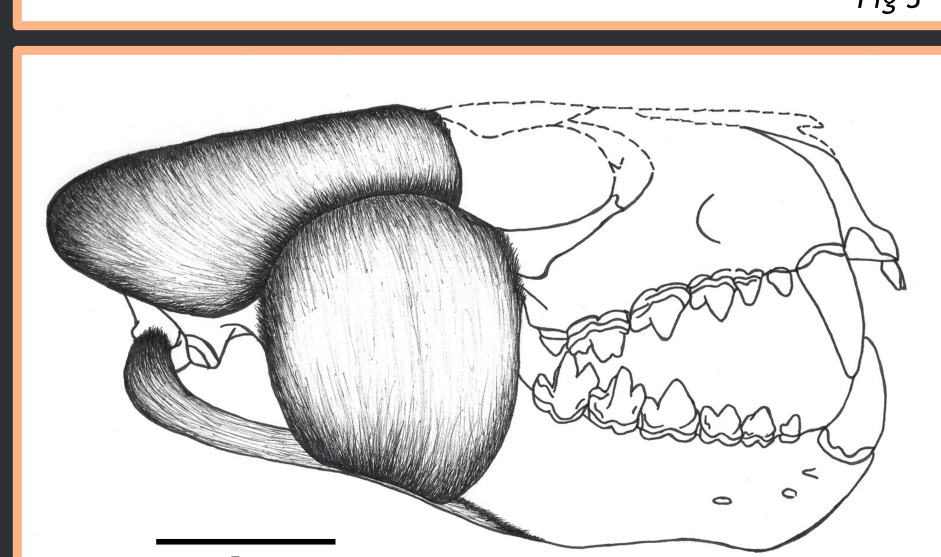


Fig 5: Lateral view of *Oxyaena* skull copied from Rose (2006). *M. temporalis*, *m. masseter*, & *m. digastricus* are illustrated on top of the Rose (2006) skull. Origins & insertions of each muscle were based off of research done on wolf skulls as well as the dissection of the dog head.

TETONIUS

Fig 2: *Tarsius syrichta* skull (BC-050) photograph taken by Dr. Fellmann. The extant specimen is housed in the Bone Lab, CSU. CSU Primate Origins Lab *Tetonius* specimen (DMNH 65043) superimposed on top of it.

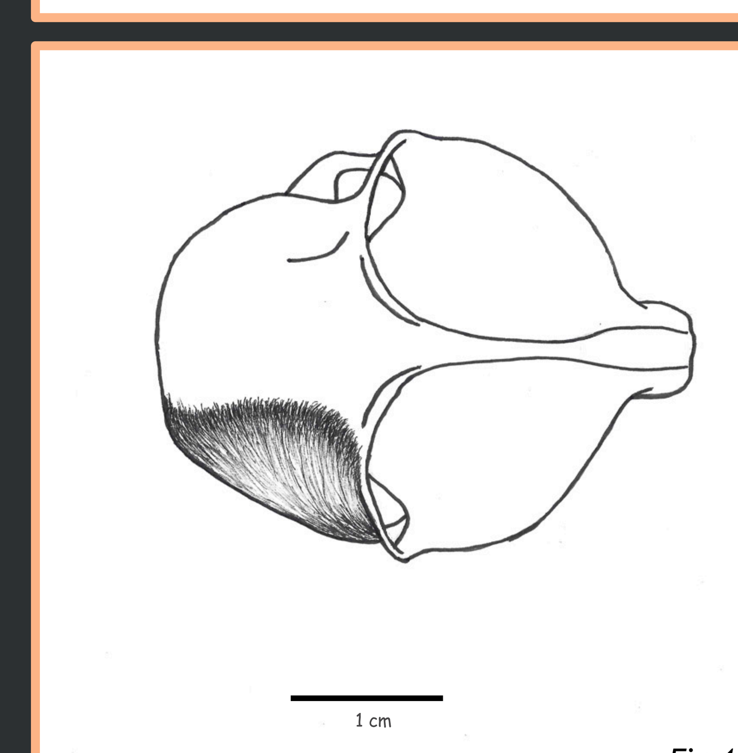


Fig 4: Superior view of *Tarsius syrichta* skull (BC-050) housed in the Bone Lab, CSU. *M. temporalis* is illustrated on top of the skull. The origin is along the sagittal crest & the insertion is along the mandibular ramus & part of the zygomatic arch (imbedding itself within *m. masseter*).

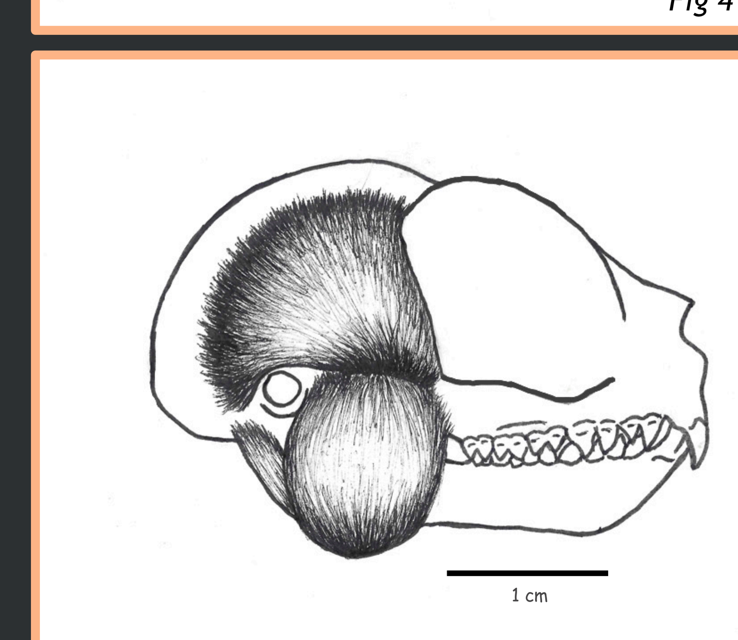


Fig 4: Lateral view of *Tarsius syrichta* skull (BC-050) housed in the Bone Lab, CSU. *M. temporalis*, *m. masseter*, & *m. digastricus* are illustrated on top of the skull. Origins & insertions of each muscle were based off of research done on wolf skulls as well as the dissection of the dog head.

CONCLUSION

Based on my comparative analysis of masticatory morphology in two Eocene mammalian faunivores, I conclude that *Oxyaena* shows major similarities towards that of *C. crocuta*, indicating a powerful bite with highly specialized dietary adaptations. I also conclude that the lack of dependence on anterior grasping/biting by the primate may be explained by manual procurement of foods with the hands rather than the face. This suggests that *Tetonius* was doing much more chewing, rather than tearing, of the food. An area of further research is an exploration in the similarities between *Tetonius/Tarsius* with cat morphology, due to the odd similarities in masticatory muscle adaptations.

BIBLIOGRAPHY

Biknevicius, Audrone R. "Functional Discrimination in the Masticatory Apparatus of Juvenile and Adult Cougars (Puma Concolor) and Spotted Hyenas (Crocuta Crocuta)." *Canadian Journal of Zoology*, vol. 74, no. 10, 1996, pp. 1934-1942., doi:10.1139/z96-218.
Booth, E. S., & Chiasson, R. B. (1989). *Laboratory anatomy of the cat*. Dubuque, IA: Brown.
Boyd S., Colin, P. R., & May, A. H. (2007). *Color atlas of clinical anatomy of the dog & cat*. London: Mosby.
Buckland-Wright, J. C. (2009). Craniological observations on Hyaena and Crocuta (Mammalia). *Journal of Zoology, 159*(1), 17-29. doi:10.1111/j.1469-7998.1969.tb03068.x
Budras, K., & Nautrup, C. P. (2002). *Anatomy of the dog: An illustrated text*. Hannover: Schlütersche.
Endo, Hideki, et al. "MRI Examination of the Masticatory Muscles in the Gray Wolf (Canis Lupus), with Special Reference to the M. Temporalis." *Journal of Veterinary Medical Science*, vol. 61, no. 6, 1999, pp. 581-586., doi:10.1292/jvms.61.581.
Field, H. E., Taylor, M. E., & Butterworth, B. B. (1969). *An atlas of cat anatomy*. Chicago, IL: University of Chicago Press.
Fleagle, John G. *Primate Adaptation and Evolution*. 2nd ed., Academic Press, 1999.
Gioso, M. A., & Carvalho, V. G. (2005). Oral anatomy of the dog and cat in veterinary dentistry practice. *Veterinary Clinics of North America: Small Animal Practice, 35*(4), 763-780. doi:10.1016/j.cvsm.2004.10.003
Rose, Kenneth D. (2006). *The Beginning of the Age of Mammals*. Baltimore, MD: Johns Hopkins University Press.
Ström, D., Holm, S., Clemensson, E., Haraldson, T., & Carlsson, G. E. (1988). Gross anatomy of the craniomandibular joint and masticatory muscles of the dog. *Archives of Oral Biology, 33*(8), 597-604. doi:10.1016/0003-9969(88)90135-5
Tseng, Zhijie Jack, et al. "Model Sensitivity and Use of the Comparative Finite Element Method in Mammalian Jaw Mechanics: Mandible Performance in the Gray Wolf." *PLoS ONE*, vol. 6, no. 4, 2011, doi:10.1371/journal.pone.0019171.

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